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RESEARCH PAPER

Putting Back the Trees: Smallholder Silvicultural Enrichment of Post-Logged Concession Forest in Peruvian Amazonia

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Abstract This paper presents a case of planting and management of natural regeneration of shihuahuaco (*Dipteryx* spp.) by recent migrants in a Peruvian Amazonian logging frontier. We interviewed residents of three communities of smallholders in Irazola District, Province of Padre Abad, Region of Ucayali, located within the historic and actual boundaries of an active logging concession, and conducted growth studies of shihuahuaco trees planted in two mixed-species agroforestry fields, over a period of 3 years. We found that the majority of landholders were managing the natural regeneration of valuable hardwood timber trees, and planting seedlings on their lands. Growth of shihuahuaco trees in agroforestry fields was comparable to growth rates in managed silvicultural plantations, which suggests the potential for local smallholders activities to contribute to conservation of genetic stock and eventual renewal of populations depleted by logging. We recommend greater recognition and inclusion of local people, with their innovative and productive silvicultural practices, in efforts to remediate the impacts of selective logging of high-value timber species.

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Introduction

Tropical forests play key roles in the regulation of global and local ecological systems and contain economic resources that directly support the livelihoods of millions of people (Scherr et al. 2004; Peluso 2005), but processes of deforestation, degradation and impoverishment of biological resources continue to alter forest cover and species composition (Oliveira et al. 2007; Schulze et al. 2008; Flores-Bendezú 2010). Despite growing global awareness, demand for forest products and resources produced on cleared forestland has impeded efforts to reverse losses primarily associated with logging and burning (Nepstad et al. 1999; Asner et al. 2005; Asner et al. 2006; Malhi et al. 2008). On the other hand, substantial areas that were once deforested have seen some form of reforestation, either through natural regeneration on unused lands or through human-managed regeneration or planting activities (Perz and Walker 2002). There are numerous examples of local forest transitions, resulting in reversion of deforested land to forest, which governments and the international community ought to encourage for carbon sequestration and other environmental reasons (Rudel et al. 2005). A global "forest tenure" transition, bringing more responsibility for forest management to communities, may lead to better forest conservation and management (Sunderlin et al. 2008; Barbier et al. 2010).

This paper presents a case of tree-planting and management of natural regeneration of shihuahuaco (*Dipteryx* spp., also known internationally as "cumaru")[1] by recent migrants to a Peruvian Amazonian logging frontier and provides support for policies that recognize the potential contribution of

[1] Shihuahuaco is the Peruvian common name for trees in the genus Dipteryx, Fabaceae, which has been variously identified as *Dipteryx odorata* (Flores-Bendezú 2002; Ricse 2007), *Dipteryx micrantha* (Reynel 2003; Romo 2005) and less frequently as *Dipteryx alata* (Putzel et al. 2010; Flores-Bendezú 2012). While it is possible that the Peruvian common name extends to several species of Dipteryx, botanical determinations of Dipteryx spp. made in Peru have not been entirely consistent, which is in part likely due to the fact that the highly polymorphic genus (Hanson et al. 2008) has not been revised since Ducke's (1940) revision. Thus, while voucher specimens of three herbaria (Universidad Nacional La Molina, New York Botanical Garden, and Missouri Botanical Garden) variously locate all three species in the immediate area of the study, it is highly likely that only one species is present and that two or more of these species may eventually be reclassified as one. It is likely for this reason that recent taxonomic work on the genus in Peru uses characteristics of congeneric species to describe one of the species (see Reynel 2003). In seedling and sapling classes, field identification is further complicated by the fact that leaf size changes substantially with light availability (personal observation). In plantation conditions in the study area in and around the von Humboldt forest, juvenile trees conformed to a local classification of shihuahuaco de hoja grande (large-leaved shihuahuaco), which local experts consider to conform to Dipteryx odorata (Flores-Bendezú 2012). In this paper, we leave the identification at the generic level, which we consider to be inconsequential in terms of our findings: all species of Dipteryx in Peru for which growth data has been collected are canopy emergent, shade tolerant at seedling stage, but fast growing as saplings and juveniles with high light availability (Romo 2005; Ricse 2007; Putzel et al. 2011). The purpose of this article is not to make a determination of the species (though the authors would be very interested in seeing an eventual systematic revision of the genus), but rather to present evidence that local smallholders planting of shihuahuaco is potentially effective, in part because growth rates are not greatly dissimilar from those found in field experiments (Romo 2005; Ricse 2007).

smallholders, including recent in-migrants, to forest management and post-logging remediation efforts. These efforts are especially important given insufficient attention to such activities on the part of the logging companies and concessionaires technically responsible for managing the forests they exploit (see, e.g. Galarza and La Serna 2005).

Logging, Migration and Deforestation

In tropical countries with endemic poverty, the links between logging, migration, and land conversion have been identified in numerous studies (see e.g. Kaimowitz et al. 1999; ITTO 2006; Merry et al. 2006). One such link is that people follow loggers into forests and convert land into agricultural fields and pastures (Haggith et al. 2003; Lima et al. 2006; Pan et al. 2007). Historically in Amazonia the phenomenon has been structurally determined, as in the state of Rondônia, Brazil, where national frontier policy encouraged migration and settlement from the south; there, for decades, farmers eked out a tenuous existence to the detriment of forest cover (Browder 1994). Some have called this process "invasive forest mobility" or IFM (Myers 1980; Repetto and Gillis 1988; Walker et al. 2002; Asner et al. 2006), a term which would seem to place people—in this case poor migrant farmers—in the category of threats to nature that need to be controlled or removed. IFM can be readily tracked from afar through examination of satellite images showing the progressive clearing of land along logging roads (Asner et al. 2006; Souza 2006). While it is indisputable that migrant settlement in forests often results in some degree of deforestation as population increases and/or soil fertility declines (see, e.g. Thiele 1993; Smith et al. 2003; White et al. 2005), the interactions between logging and smallholders and their relative effects on land cover are more complex than satellite imagery alone can illustrate.

In Amazonia, most logging not conducted for the explicit purpose of clearing land is selective logging, concentrated on the extraction of valuable and usually low-density species currently demanded by the market (Browder 1987; Kaimowitz et al. 1999; Pinedo-Vasquez et al. 2001; Asner et al. 2005; Asner et al. 2006; Souza 2006). In this decade, the composition of marketable species from Peruvian Amazonia has changed greatly, both due to the emergence of new markets—most notably the Chinese market for hardwood flooring—and to single-species protection measures especially targeting mahogany (*Swietenia macrophylla*) and tropical cedar (*Cedrela* spp.) (Putzel et al. 2008). Peru's national legislative environment has also changed substantially, resulting in a new zoning of timber concessions, protected areas, and indigenous reserves (Smith et al. 2006; Galarza and La Serna 2005; Oliveira et al. 2007). With these changes, logging companies are entering new areas and returning to areas logged previously in search of currently profitable timber species, such as shihuahuaco, quinilla (*Manilkara bidentata*) and estoraque (*Miroxylon balsamum*), and others. In the process, new roads must be built, and old ones improved, which brings new people and new activities into places previously more difficult to access.

In Peruvian Amazonia, logging is a precursor to migration, and migration is a precursor to land cover change (Lima et al. 2006; Pan et al. 2007). However, this paper supports previous findings that post-migration land cover change is not simply

deforestation, especially in the context of smallholder land management: it is many other things, including farming, reforestation and management of natural regeneration to enrich future timber stocks.

Land Tenure Security and Forest Transition

In contrast to ideas about "invasive forest mobility," which associates the migration of people into forested areas with deforestation, the hypothesis of land tenure security (LTS) proposes that with secure land rights, farmers will better manage and conserve resources, including forests (Mueller 1997; Walker et al. 2002). Barbier et al. (2010) refer to a global forest tenure transition from government to community and private ownership which will likely improve forest conservation and management and, their analysis suggests, contribute to shifting the curve of deforestation to a curve of reforestation along lines proposed by Mather (1992), Grainger (1995), Rudel (1998), Rudel et al. (2005), and others. While Walker et al. (2002) found LTS did not necessarily prevent deforestation by smallholders in Pará, Brazil, it likely reduced the participation in logging and increased the conservation of hardwoods in smallholdings (Walker et al. 2002). Another analysis in the same area found that duration of tenure positively affected growth of secondary forest cover (Perz and Walker 2002). In a comparative study of reforestation by smallholders in Brazil and Panama, Simmons et al. (2002) found that LTS increased by 15.4 times the probability of tree planting activities in both countries.

In Peru, even as the new forest laws were created and implemented in the last decade to encourage conservation and sustainable management of natural forests, a major initiative to formalize the land ownership of informal landholders that began under the administration of Fujimori in 1996 (Cockburn 2004) was extended from urban to rural areas. By February 2007, over 22,000 parcels had been formally titled in the Amazonian region of Ucayali, accompanied by governmental investment "shocks" designed to improve infrastructures (COFOPRI 2007).[2] The lack of harmonization between the forestry and land titling policies results in a legal gray area where migrants can be granted titles to land even within the boundaries of a forest concession. In addition, a logging concession can be granted despite the presence of local inhabitants with claims to the land, a phenomenon also observed in Amazonian countries other than Peru (see, e.g. Contreras-Hermosilla and Vargas 2002; FPP 2004; ITTO 2006). An important illustration of the limitations of collaboration between institutions of forestry zoning and land titling, is the fact that the governmental bodies responsible for administering the two systems do not use the same computer programs: natural resources are mapped with geographic information systems (GIS) software, while titled land parcels are stored in computer-aided design (CAD) software.

[2] At the time of the fieldwork done for this study, the initiative to formalize rural land titles was undertaken by the national agency COFOPRI, but has since been devolved to a dedicated office at the region level.

Smallholder Forest Management and Reforestation

Recent studies of timber production by Peruvian smallholders have focused on the production of fast-growing timber species, such as bolaina blanca (*Guazuma crinita*) and capirona (*Calycophyllum spruceanum*) in fallows, and recognized the validity of local people's resource management practices (Padoch and Pinedo-Vasquez 1996; Sears 2003; Sears and Pinedo-Vasquez 2004).

However, although less common, the planting or management of slow-growing hardwood timbers for the use of future generations is also a well-documented phenomenon (see, e.g. Peluso 1992). Simmons et al. (2002) found that, in Brazil, farmers planted a number of slow growing timber trees such as mahogany, cedar, and ipê (*Tabebuia* spp.), often within mixed plantations of cacao and/or coffee, without expecting to harvest those timbers in their lifetimes.

In the literature on smallholder-forest interactions, as pointed out by Summers et al. (2004), most discussions of sustainable smallholder forestry focuses on "traditional" populations, while "non-traditional" populations, such as non-indigenous residents of forest regions as well as recent migrants, are generally associated with studies of deforestation and land-use change. In fact, not only do "non-traditional" people employ local knowledge of silviculture, they hybridize and adapt local and "science-based" knowledges from many sources, including extension agents and sources of market information (see, e.g. Sears et al. 2007).

In forestland recently settled largely by migrants from other regions of Peru—i.e. non-traditional residents—it is counterintuitive to expect the long-term perspective accompanying the planting of slow-growing timbers. It would certainly be careless, considering rural poverty levels, to encourage residents to devote their time and space to activities that might not benefit them in their lifetime. Nonetheless, in areas located in and around logging areas near Pucallpa, in the Region of Ucayali, Peru, smallholders do plant shihuahuaco seedlings within their very diverse agricultural and agroforestry fields. Belonging to the genus *Dipteryx*, shihuahuaco is an ecologically important rainforest species, which emerges over the surrounding canopy and provides important nutrition in the form of its fruit and seeds, which mature in the dry season, as well as habitat to native birds and mammals, for which it can be called a "keystone" tree species (Brightsmith 2005). Although *Dipteryx* spp. are likely very slow to mature in natural conditions (Chambers et al. 1998; Clark and Clark 2001), with greater light availability at juvenile life stages they can mature and grow very quickly, achieving heights of up to 5 m in 2 years (Romo 2005) or 11.5 m in 6 years (Ricse 2007). However, in natural conditions, opportunities for growth are limited by the scarcity of gaps in the canopy (Romo 2005), whereas in post-logging areas and areas under smallholder management, such opportunities could be increased under certain conditions, provided the degree of permanent land conversion is not too high (Putzel et al. 2011). To better understand the involvement of local smallholders in shihuahuaco management, we visited several communities in logging areas to better understand how and why they plant or manage shihuahuaco trees, and to get a sense of whether, in the short term, smallholder planted trees were likely to be viable.

Methods

Study Area

Irazola District, Province of Padre Abad in the Region of Ucayali, covers an area of 2,006.98 km^2 and is located between the urban centers of Pucallpa and Aguaytía, which are connected to each other by the Federico Basadre Highway, which continues on over the Andes to the coast and to Lima. In recent years, according to provincial documents, the population of the province multiplied, mainly due to a boom in coca production which attracted migrants from the Sierra Central, which is located on the Amazonian side of the Andes and is more culturally similar to the Amazon region than to other parts of the Andes and the coast. The District now comprises ca. 57 population centers including the district capital of San Alejandro; in 2005 the district population was 16,192. Overall, the rural population of Padre Abad Province increased from 5,679 in 1981 to 19,793 in 1993 and 23,868 in 2007. The majority of Irazola district lies within the boundaries of the 4,074 km^2 Alexander von Humboldt national forest, which is a designated permanent production forest as well as the site of a number of logging concessions. Around and within these concessions, there are a number of permanently settled population centers. In recognition of the establishment of population centers within the boundaries of the national forest, the National Ministry of Agriculture excluded 13,450 ha from the national forest in 1999. However, since then migration has continued both within the national forest and into the forest concessions.

Research Methods

In 2007 several communities of smallholders were identified in Irazola District, Province of Padre Abad, Region of Ucayali, within the historic and actual boundaries of a timber concession. At that time, it was noted that some families were actively managing residual trees of shihuahuaco as well as transplanting seedlings of the same genus in their agricultural fields. Data were collected on the growth rates of these trees in the fields of two farmers (Farm A and Farm B), the first measuring 2 ha, the second 1 ha, over three years in September 2007, September 2008, and October 2009. The trees had been transplanted as seedlings 1 year prior to the study, and the original size of the seedlings was not known.

In 2009, in-depth semi-structured interviews were conducted with 30 families in three communities. To overcome the challenges of sampling a population of farmers distributed over large areas, frequently absent or following a daytime schedule of working in their remote fields, individuals interviewed were selected using the principle of first opportunity, as described by Walker et al. (2002).

Data collected included information on the settlement and logging histories of the communities, reported landholdings and associated land uses, and the nature and extent of local involvement and interest in replanting initiatives. In particular, interviews focused on community members' management and replanting of *Dipteryx*, a slow-growing hardwood tree. In addition, several interviews were conducted with the owner of the timber concession contract. The results of these

interviews are presented here, with additional background information derived from provincial documentation. Additionally, we present the results of 3 years of growth data collection on *Dipteryx* trees planted by in the fields of Farm A and Farm B.

Results

Description of Communities and Land Tenure

Communities A, B, and C are located on the fringes of a 15,000 ha timber concession established in the 1980s but subsequently abandoned for more than a decade due to civil unrest. The concession contract was renewed in 2005 under the new forestry legislation.

Relations between the communities, the company that owns the concession contract, and subcontracting logging companies vary a great deal. Community A and B are joined by a road built with funds from a US government "alternative development" program aimed at eliminating coca production in the area. While technically not intended for the passage of heavy vehicles, logging trucks use the road and pay a toll to the communities. In Community B, which lies closer to the current logging zones, land tenure disagreements with the concessionaire and loggers result in frequent confrontation. Communities A and C, which lie further from current logging areas have fewer difficulties in their interactions with extractors.

The logging history of the three communities as well as the concession is complex. Since the early 1990s, the area has been selectively logged repeatedly by a multitude of extractive companies and individual loggers, both with and without permits. The first species to be removed included mahogany (*S. macrophylla)*, tropical cedar (*Cedrela* spp.) and ishpingo (*Amburana cearensis*); in this decade, the most demanded species have included azucarhuayo (*Hymenaea courbaril*), aguanomasha (*Machaerium inundatum*), quinilla (*M. bidentata*), estoraque (*M. balsamum*), and shihuahuaco (*Dipteryx* spp.). Recently, demand for shihuahuaco timber has resulted in a race for the resource between local residents and extractors. While companies may pay residents between $10 and $35 per tree on contested land (whether or not it is legally located within the concession) families with sufficient available human resources can earn more by cutting trees themselves and selling the timber in chainsawed blocks at around $0.30 per board foot ($127 per m^3). Alternatively, since shihuahuaco charcoal is among the best in the market, they often salvage branches left by loggers or cut standing trees to produce charcoal, which sold at up to $15.00 per cubic meter in 2008.

Land tenure in all three communities has been relatively fluid because the majority of residents obtained the land through informal settlement followed by a process of formalization. The first step in obtaining title is to obtain a document from the regional government called a *constancia de poseción*, which recognizes a family's possession, location and area of a parcel of land without attesting to their right to own it. However, constancias are valid as proof of occupancy and are accepted as the basis for titling by the national organization COFOPRI, thus they

constitute a type of formal tenure. Most families interviewed claimed formal ownership of a portion of their land while claiming informal rights to additional lands. Especially in Community B, the concession owner contests the rights of residents to occupy lands well within the bounds of the concession and has made efforts to restrict their activities and expansion. Overall, in the three communities families claimed formal ownership of an average 21.9 ha and informal tenure of an average additional 30.8 ha ($P = 0.0407$). Thus, the average area of combined formal and informal landholdings is around 53 ha per family.

The average length of residence among respondents was 8.5 years, though in Communities A and B the earliest residents arrived up to 20 years ago, and in each place one family interviewed claimed to be among the first occupants of the community. Community A, the oldest of the three communities, was officially founded in 1996, while Community C, the newest community was founded in 2002. Although the migration history of individual families is very diverse, the majority of people in the area come from either Huanuco or San Martin, on the Amazonian or eastern side of the Andes.

There is some variation in land uses among the communities. All families report a certain amount of land for mixed agricultural production (including maize, plantain, cassava, dryland rice, etc.). In Communities A and B extension programs have promoted the production of oil palm and agroforestry including cacao. Residents speak of receiving palm and cacao seedlings in quantities of "hectares," i.e. enough seedlings to cover one hectare. However, while oil palm is planted in monoculture, cacao is planted in mixed agricultural systems which sometimes include both fast- and slow-growing timber trees. Cattle pastures are common, but are not the primary means of subsistence in the area. On average, families report holding an average of 4.6 ha in mixed agriculture, including subsistence production (*chacra*) and plantations of cacao and oil palm; 3.74 ha of pasture (*pasto*); 8.88 ha of secondary fallow (*purma*); and 20.32 ha of standing forest (*monte alto*). The reported amount of standing forest held by each family correlates positively to the size of their informal land holdings.

Post-logging tree planting and management of natural regeneration

In interviews, 76 % of respondents were aware of shihuahuaco residual seedlings or saplings growing in the forested parts of their landholdings. While 72 % claimed to be active in management of other species, such as cedar (*Cedrela odorata*), ishpingo (*A. cearensis*), capirona (*C. spruceanum*), and bolaina blanca (*G. crinita*) fewer (56 %) were actively managing shihuahuaco. In addition to management, which primarily involves liberation of seedlings or saplings through clearing and thinning, 52 % of respondents reported that they planted timber trees, by transplanting seedlings found in the forest, delivered by extension agents, or by raising them in small nurseries. Answering an open ended question as to the rationale for replanting trees, roughly one-third (n = 11) of respondents mentioned environmental protection as a primary concern, including maintaining atmospheric quality (e.g. "purifying the air"), protecting the water supply, and providing habitat for animals. A number of respondents (n = 7) cited benefit to future generations and especially

to their own grandchildren as the primary reason to plant valuable timber trees. Several respondents who plant or manage trees for their own economic benefit primarily concentrate on faster-growing species. Overall, the probability of residents engaging in tree planting appeared to be associated with the length of time they had lived in the area.

While it appeared that a number of respondents were self-motivated in managing or replanting timber species, it was obvious that external influences had been important in the area. Although the concessionaire was accused of neglecting reforestation, one respondent who had worked for 2 years as a woodsman volunteered that the concessionaire had hired local residents to create a nursery for timber trees for the purposes of enriching the concession. When the concessionaire allegedly failed to pay for the work, the trees were sold to an alternative development project and they were distributed to local farmers. In 2006, a project delivered tree seedlings and fertilizer to farmers in Community A as part of a project to relieve pressure on the natural forest, to "stabilize" farmers, and to promote environmental education. The project was supposed to provide credit to participants, but it closed down shortly after reaching our study area. Problems associated with the project included the failure of some farmers to plant the seedlings they were given, and the loss of planted trees to escaped fires from neighbors' fields during a drought in 2005. We present below growth data from one field where seedlings from this project were planted. Finally, an association of Agriculture and Forest Producers of Monte Alegre (ACPAFMA), started in 2005 by a local politician, has attracted 330 members in 21 communities in the district, including Communities A, B and C. The association is seeking funding for mixed cacao and timber agroforestry projects.

Although the degree of general environmental concern expressed by respondents was high and many considered planting timber worthwhile for the purpose of providing resources for future generations, many also complained about lack of support from external sources of funding. While the combination of cacao and timber seems to be successful, such land use will have to compete with expanding smallholder oil palm plantations which is heavily subsidized by alternative development projects. At the entrance to the area from the Federico Basadre Highway there is an oil extraction plant, whereas the closest processing facility for cacao is located in Tingo Maria, Department of Huanuco, more that 200 km from the area. Nonetheless, planters of cacao prefer it because it requires less labor, and appear willing to experiment with timber production in a mixed system.

Performance of Shihuahuaco Juveniles in Agricultural Fields

The average growth rate of individuals in the field of Farm A and B between 2007 and 2008 was 49 and 75 % in terms of height and diameter, respectively. From 2008 to 2009, the average growth rate slowed to 31 and 24 %, respectively. No significant difference was identified between the two farms (Table 1); however, inspection of the data shows an apparent slowing of diameter growth in Farm B, where the trees were planted on well-drained slopes, versus Farm A, where the trees were planted on a flat area surrounded by streams (Fig. 1).

Table 1 Growth of shihuahuaco juveniles in fields of Farm A and Farm B

Year	n	Mean diameter (cm) ± SD	Mean height (cm) ± SD
Farm A			
2007	30	2.79 ± 1.16	353 ± 120
2008	30	5.20 ± 1.75	549 ± 167
2009	30	6.93 ± 2.14	711 ± 179
Farm B			
2007	47	3.35 ± 1.65	371 ± 160
2008	45	5.66 ± 2.09	538 ± 220
2009	44	6.73 ± 2.75	709 ± 260

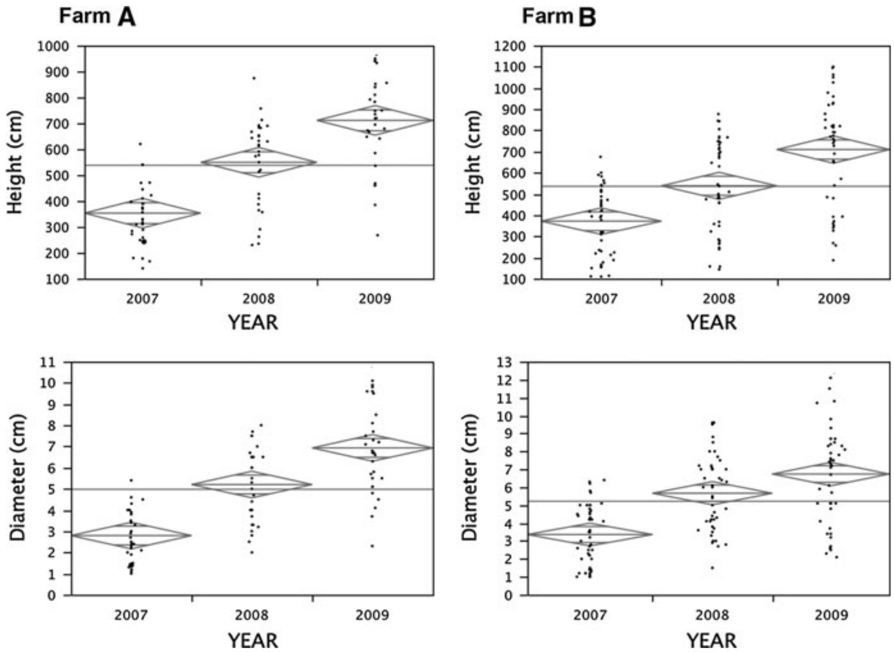

Fig. 1 Growth of shihuahuaco spp. juveniles in height (*top*) and diameter (*bottom*) on Farm A and Farm B over a 3 year period from 2007 to 2009. *Diamonds* indicate the mean (*central line*) and the standard deviations (lines parallel to means)

Overall, growth in height was 178 cm from year 1 to year 2 (from 364.13 ± SD145.07 to 542.8 ± SD199.09 cm) and from year 2 to year 3, 167 cm (542.8 ± SD199.09 to 710.22 ± SD229.02). Growth in diameter from year 1 to year 2 was 2.35 cm (from 3.14 ± SD1.5 to 5.48 ± SD1.96 cm) and from year 2 to year 3, 1.33 cm (from 5.48 ± SD1.96 to 6.81 ± SD2.5 cm). A two-way analysis of variance shows significant growth from year-to-year, with no significant difference between farms (Table 2).

Table 2 Two-way ANOVA showing change in height and diameter is significantly related to age*, and not to the location of study sites

	SS	*df*	*MS*	*F*	*P* value
Two-way analysis of variance—height (cm)					
Model	4,524,054	3	1,508,018	40.0393	<.0001
Error	8,361,289	222	37,663		
Total	12,885,343	225			
Effect tests					
Farm	186.1	1		0.0049	.944
Year	5,423,842	2		60.0561	<.0001*
$R^2 = 0.35$					
Two-way analysis of variance—diameter (cm)					
Model	528.39	3	176.130	43.0628	<.0001
Error	907.9974	222	4.09		
Total	1436.39	225			
Effect tests					
Farm	4.25	1		1.0397	.3090
Year	525.31	2		64.2179	<.0001*
$R^2 = 0.37$					

Discussion

In forest concession areas of the Von Humboldt national forest in Irazola district, as elsewhere in Peru, there are overlapping areas of forest concession and farming communities. Migration has occurred both during periods of active logging, when concession contracts have been in effect, and during in-between periods when concession contracts have lapsed. The earliest current residents of the area only arrived at the end of the 1980 s, when logging companies were active in the area and logging roads had been cut, and it can therefore be assumed that logging facilitated access to the area. As selectively logged land has been occupied by migrants, the area of the permanent production forest has been officially reduced, and with the national drive to formalize land ownership families have been granted titles both within the limits of the national forest and an active timber concession.

The gradual occupation of post-logged land in Irazola—because it occurs gradually, without planning, and follows logging roads—could be termed an invasive phenomenon. In the absence of such land acquisition and transformation, gaps created through logging would be closed by a suite of locally adapted gap-colonizing species and the forest cover would remain largely intact. In terms of species composition, however, the residual forest would likely be impoverished, especially from an economic perspective: without management, selective logging results in a shortage of key economic species and a severely reduced potential for recovery due to the removal of seed trees. To date, there is little evidence that timber concessionaires and logging companies are involved in efforts to replant timber species or manage natural regeneration of logged areas. While the arrival of

migrants results in transformation of the landscape from forest to a mosaic of different land uses, the presence of people may increase the potential for replacement of valuable timber species, as has been observed in other locations by Peluso (1992), Padoch and Pinedo-Vasquez (1996), Simmons et al. (2002), Sears et al. (2007) and others.

This study focused on *Dipteryx* spp. Although we did not quantify the planting of *Dipteryx* versus other timber species, we found that it was a species of particular interest to farmers in the area. Our measurements of the growth of shihuahuaco trees in two mixed agroforestry fields were comparable to the fastest growth rates of the species *Dipteryx micrantha* previously observed in "pure plantations" (Romo 2005), suggesting that this treatment of the species is likely to result in a future standing stock of these particularly valuable trees. Romo (2005) found that seedlings reached a height of almost 5 m and a diameter of about 5 cm after 2 years of growth. In the second year of our study, i.e. ca. 2 years after planting, the juveniles we measured in Farms A and Farm B ($n = 75$) reached an average diameter of 5.48 cm $\pm$ 1.96 and height of 542.8 $\pm$ 199.08 cm. We were not able to measure the initial size of these individuals, since they had been planted in the year previous to the beginning of our study.

In this study we found that not only were the majority of landholders managing the natural regeneration of timber trees, but were also planting seedlings on their lands. We argue that these activities indicate not only a wish to obtain future economic benefit from timber, but an intention to maintain areas with tree cover, or to allow timber trees to recover areas currently being used for other purposes. Such activities are common among smallholder farmers that occupy tropical forest regions, and therefore should not come as a surprise. However, there are several points suggested by this study that are important to highlight. These are:

1. *Recent migrants engage in post-logging reforestation.* Through management of natural regeneration and replanting of timber species removed through logging operations, recent migrants in the study region promote the enrichment of residual forest as well as current fallows and mixed agricultural fields with hardwood timbers now valuable in the market.
2. *Smallholder management contributes to conservation of local genetic diversity.* By managing residual saplings and collecting seeds from trees of species currently being cut in timber concession land and production forest, smallholders conserve genetic diversity which might otherwise be permanently lost. Although this genetic diversity is likely lower than that which existed in pre-logging conditions due to the likelihood that farmers collect large numbers of seeds from specific individual trees, at the landscape level it nonetheless must represent an incremental positive effect compared to the potential loss if no seeds of logged adults were to be collected and planted.
3. *Reforestation practices are influenced by extension projects.* Although the success of extension projects promoting integration of timber production in agroforestry is mixed, the majority of people interviewed in our study were aware of these projects. The production of cacao and coffee interspersed with timber trees, which has been promoted in the area, is a form of cultivation that

is known to work in other locations (Simmons et al. 2002), and represents an alternative to monocultural plantations such as oil palm, which is also being heavily promoted in the area. The hybridization of knowledge highlighted by Sears et al. (2007) is also apparent: while some farmers receive materials and follow the guidelines of extension projects, others improvise by collecting seeds and planting trees in their mixed agricultural fields from seedlings produced in their own nurseries.

4. Finally, *land tenure security in the study area may have been increased by the process of land title formalization* under COFOPRI, which is now conducted by the regional government. The fact that migrants have been granted title to their land in the area may increase their interest in long-term inter-generational management of timber trees. However, the long-term stability of communities depends on economic viability. In other studies, it has been found that the first occupants of newly opened forest areas are not necessarily present for the long term, and that titling may result in land sales (Walker et al. 2002). It has also been suggested that communal management, in the context of state-community partnerships, would be more effective than private ownership (Alcorn 1996). Nonetheless, while land titled by the government is private, residents of Irazola communities showed an eagerness to join communal efforts such as ACPAFMA to obtain a combination of plantation materials such as cacao plants and timber seedlings.

Conclusion

Although the Peruvian forest law requires that timber concessionaires submit a plan for post-logging reforestation, in reality there is currently no evidence that concession holders or timber companies maintain a workforce that would be capable of such work. Migration of people to post-logged forest land results in the conversion of the landscape into a mosaic of different land cover types, and forest cover likely does not increase to its original extent while it is used by subsistence farmers (Rudel et al. 2005). However, it is important to recognize that management and planting by smallholders, including recent migrants, contributes to the conservation of timber tree genetic diversity and to the enrichment of forests for future generations. The activities of extension agents to provide seedlings leave an impression, not only among those smallholders that accept and plant the seedlings, but also in the minds of people who have not yet participated, supporting previous findings that smallholders are receptive to receiving knowledge and materials from many sources.

Our findings show that smallholders, even if they are relatively new to an area, have an interest in engaging in reforestation of valuable trees, and that their observation of the removal of valuable resources and contact with extension programs may increase that interest. This finding suggests that there is a window in the deforestation process in which irreplaceable future genetic stock, represented by the seeds and seedlings of at least a proportion of felled adult trees, might be

conserved and the future availability of timber for which there is currently high demand might be increased. However, this study does not suggest that devoting large areas of land to the growing of slow-growing trees will satisfy the current livelihood needs of smallholders in tropical rainforests. There are obvious trade-offs between managing a landscape for timber production versus agricultural production and pastureland, and farmers must try to make the best decisions as to what extent it is beneficial to engage in various productive activities. Additionally, there continues to be ambiguity of land and resource tenure between smallholders and timber concessionaires on the forest frontier, despite the efforts of national land titling programs to stabilize tenure.

To inform policies that facilitate farmer decision-making regarding these trade-offs, additional research continues to be needed on the relationships between land tenure (security, size of holdings) and maintenance and creation of biodiverse agricultural-forest mosaics, in which many types of food crop, livestock, and both fast- and slow-growing trees may be produced. In the meantime, actors with an interest in maintaining timber species diversity and stocks in the future, including timber companies and government natural resource agencies are encouraged to explore ways to engage local residents, for example through the agricultural associations they belong to, in collection of seeds, maintenance of tree nurseries, and management of natural regeneration in the forested areas they regularly occupy or visit. Such efforts could help to remediate the effects of selective logging to some extent, in areas where post-logging forest cover is maintained, if more opportunities were created for local people to participate in forestry, even on concession lands. In lands being occupied and converted following logging, conservation of timber species in agriculture-forest mosaics may be even more crucial in the long run.

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References

Alcorn J (1996) Forest use and ownership: patterns, issues and recommendations. In: Schelhas J, Greenberg R (eds) Forest patches in tropical landscapes. Island Press, Washington, DC, pp 233–257

Asner GP, Knapp DE, Broadbent EN, Oliveira PJC, Keller M, Silva JNM (2005) Selective logging in the Brazilian Amazon. Sci 310:480–482

Asner GP, Broadbent EN, Oliveira PJC, Keller M, Knapp DE, Silva JNM (2006) Condition and fate of logged forests in the Brazilian Amazon. Pub Nat Acad Sci 103:12947–12950

Barbier EB, Burgess JC, Grainger A (2010) The forest transition: towards a more comprehensive theoretical framework. Land Use Policy 27:98–107

Brightsmith DJ (2005) Parrot nesting in Southeastern Peru: seasonal patterns and keystone trees. Wilson Bull 117:269–305

Browder JO (1987) Brazil's export promotion policy (1980–1984): impacts on the Amazon's industrial wood sector. J Dev Areas 21:285–304
Browder JO (1994) Surviving in Rondônia: dynamics of colonist farming strategies in Brazil's Northwest frontier. Stud Comp Int Dev 29:45–69
Chambers JQ, Higuchi N, Shimel JP (1998) Ancient trees in Amazonia. Nature 391:135–136
Clark DA, Clark DB (2001) Getting to the canopy: tree height growth in a neotropical rainforest. Ecology 82:1460–1472
Cockburn JC (2004) La formalización de la propriedad en el Perú: Efectos económicos y socio culturales. Ponencia al Cuarto Seminario Internacional Innovando los procesos de acceso al suelo urbano. Universidad Nacional Autónomo de México, México D.F. 6–7 July 2004
COFOPRI (2007) Ministro de Vivienda entregó 976 títulos de propiedad en Ucayali. Organismo de la Formalización de la Propriedad Informal. http://www.cofopri.gob.pe/pren_ver_detnot.asp?cod=78&img=1. Accessed 9 August 2011
Contreras-Hermosilla A, Vargas MT (2002) Social, environmental and economic dimensions of forest policy reforms in Bolivia. Forest Trends, Washington, DC
Ducke A (1940) Revision of the genus *Coumarouna* Aubl. or *Dipteryx* Schreb. Trop Woods 61:1–10
Flores-Bendezú Y (2002) Semillas de especies forestales de importancia economica en la Región Ucayali. Instituto Nacional de Innovación Agraria, Lima
Flores-Bendezú Y (2010) Crecimiento y productividad de plantaciones forestales en la Amazonía Peruana. Instituto Nacional de Innovación Agraria, Lima
Flores-Bendezú Y (2012) Experiencias con shihuahuaco en von Humboldt. http://vonhumboldtinia.blogspot.com/2012/08/experiencias-con-shihuahuaco-en-von.html. Accessed 30 August 2012
FPP (2004) Indigenous peoples in the Peruvian Amazon call for forest policy reform and major changes in implementation of the Forest Law. For People's Program. http://archive.forestpeoples.org/documents/s_c_america/peru_ips_wshps_forestry_oct04_sp.shtml. Accessed 9 August 2011
Galarza E, La Serna KL (2005) ¿Son sostenibles las concesiones forestales en el Perú? Econ Soc 56:34–41
Grainger A (1995) The forest transition: an alternative approach. Area 27:242–251
Haggith M, Muetzelfeldt RI, Taylor J (2003) Modelling decision-making in rural communities at the forest margin. Small Scale For Econ Manag Pol 2:241–258
Hanson TR, Brunsfeld SJ, Finegan B, Waits LP (2008) Characterization of microsatellite markers for the almendro (*Dipteryx panamensis*), a tetraploid rainforest tree. Mol Ecol Res 8:425–427
ITTO (2006) Status of tropical forest management 2005. ITTO technical series no 24. International Tropical Timber Organization, Yokohama
Kaimowitz D, Thiele G, Pacheco P (1999) The effects of structural adjustment on deforestation and forest degradation in lowland Bolivia. World Dev 27:505–520
Lima E, Merry F, Nepstad D, Amacher G, Azevedo-Ramos C, Lefebvre P, Resque F Jr (2006) Searching for sustainability: forest policies, smallholders and the trans-Amazonian highway. Environment 48:26–38
Malhi Y, Roberts JT, Betts RA, Killeen TJ, Li W, Nobre CA (2008) Climate change, deforestation, and the fate of the Amazon. Science 319:169–172
Mather AS (1992) The forest transition. Area 24:367–379
Merry F, Amacher G, Macqeen D, Santos MGD, Lima E, Nepstad D (2006) Collective action without collective ownership: community associations and logging on the Amazon frontier. Int For Rev 8:211–221
Mueller B (1997) Property rights and the evolution of a frontier. Land Econ 73:42–57
Myers N (1980) The present status and future prospects of tropical moist forest. Environ Conserv 7:101–114
Nepstad D, Veríssimo A, Alencar A, Nobre C, Lima E, Lefebvre P, Schlesinger P, Potter C, Moutinho P, Mendoza E, Cochrane M (1999) Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398:505–508
Oliveira PJC, Asner GP, Knapp DE, Almeyda A, Galván-Gildemeister R, Keene S, Raybin RF, Smith RC (2007) Land-use allocation protects the Peruvian Amazon. Sci 317:1233–1236
Padoch C, Pinedo-Vasquez M (1996) Smallholder forest management: looking beyond non-timber forest products. In: Ruiz Pérez M, Arnold JEM (eds) Current Issues in non-timber forest products research. Center for International Forestry Research, Bogor, pp 103–117
Pan W, Carr D, Barbieri A, Bilsborrow R, Suchindran C (2007) Forest clearing in the Ecuadorian Amazon: a studyof patterns over space and time. Popul Res Pol Rev 26:635–659

Peluso NL (1992) The ironwood problem: (Mis)management and development of an extractive rainforest product. Conserv Biol 6:210–219
Peluso NL (2005) Whose woods are these? Counter-mapping forest territories in Kalimantan, Indonesia. In: Edelman M, Haugerud A (eds) The anthropology of development and globalization: From classical political economy to contemporary neoliberalism. Blackwell, Oxford, pp 273–281
Perz SG, Walker RT (2002) Household life cycles and secondary forest cover among small farm colonists in the Amazon. World Dev 30:1009–1027
Pinedo-Vasquez M, Zarin DJ, Coffey K, Padoch C, Rabelo F (2001) Post-boom logging in Amazonia. Hum Ecol 29:219–239
Putzel L, Padoch C, Pinedo-Vasquez M (2008) The Chinese timber trade and the logging of Peruvian Amazonia. Conserv Biol 22:1659–1661
Putzel L, Peters C, Romo M (2011) Post-logging regeneration and recruitment of shihuahuaco (*Dipteryx* spp.) in Peruvian Amazonia: implications for management. For Ecol Manag 261:1099–1105
Repetto R, Gillis M (1988) Public policies and the misuse of forest resources. Cambridge University Press, Cambridge
Reynel, C, Pennington RT, Pennington TD, Flores C, Daza A (2003) Árboles útiles de la Amazonia Peruana: Un manual con apuntes de identificación y propagación de las especies
Ricse A (2007) Rehabilitación de suelos forestales en ultisoles degradados en el Bosque Alexander von Humboldt. Instituto Nacional de Innovación Agraria, Lima
Romo M (2005) Efecto de la luz en el crecimiento de plantulas de *Dipteryx micrantha* Harms "Shihuahuaco" transplantadas a sotobosque, claros y plantaciones. Ecol Aplica 1–2:1–8
Rudel TK (1998) Is there a forest transition? Deforestation, reforestation and development. Rur Sociol 63:533–552
Rudel TK, Coomes OT, Moran E, Achard F, Angelsen A, Xu J, Lambin E (2005) Forest transitions: towards a global understanding of land use change. Glob Env Chang 15:23–31
Scherr SJ, White A, Kaimowitz D (2004) A new agenda for forest conservation and poverty reduction: making markets work for low-income producers. Forest Trends, Washington DC
Schulze M, Grogan J, Landis M, Vidal E (2008) How rare is too rare to harvest? Management challenges posed by timber species occurring at low densities in the Brazilian Amazon. For Ecol Manag 256:1443–1457
Sears R (2003) New forestry on the floodplain: the ecology and management of *Calycophyllum spruceanum* (Rubiaceae) on the Amazon landscape. Dissertation, Columbia University
Sears R, Pinedo-Vasquez M (2004) Axing the trees, growing the forest: smallholder timber production on the Amazon Várzea. In: Daniel Z (ed) Working forests in the neotropics: conservation through sustainable management?. Columbia University Press, New York, pp 258–278
Sears R, Padoch C, Pinedo-Vasquez M (2007) Amazon forestry tranformed: integrating knowledge for smallholder timber management in eastern Brazil. Hum Ecol 35:697–707
Simmons CS, Walker RT, Wood CH (2002) Tree planting by small producers in the tropics: a comparative study of Brazil and Panama. Agrofor Syst 56:89–105
Smith J, Ferreira S, Kop PVD, Ferreira CP, Sabogal C (2003) The persistence of secondary forests on colonist farms in the Brazilian Amazon. Agrofor Syst 58:125–135
Smith J, Colan V, Sabogal C, Snook L (2006) Why policy reforms fail to improve logging practices: the role of governance and norms in Peru. For Pol Econ 8:458–469
Souza CM (2006) Mapping land use of tropical regions from space. Pub Nat Acad Sci 103:14261–14262
Summers PM, Browder JO, Pedlowski MA (2004) Tropical forest management and silvicultural practices by small farmers in the Brazilian Amazon: recent farm-level evidence from Rondônia. For Ecol Manag 192:161–177
Sunderlin WD, Hatcher J, Liddle M (2008) From exclusion to ownership? Challenges and opportunities in advocating forest tenure reform. Rights and Resources Initiative, Washington, DC
Thiele G (1993) The dynamics of farm development in the Amazon: the Barbecho crisis model. Agric Syst 42:179–197
Walker R, Wood CH, Skole D, Chomentowski W (2002) The impact of land titling on tropical forest resources. In: Walsh SJ, Crews-Meyer KA (eds) Linking people, place, and policy: a GIScience Approach. Kluwer Academic Publishers, Boston, pp 131–153
White D, Arca M, Alegre J, Yanggen D, Labarta R, Weber JC, Sotelo-Montes C, Vidaurre H (2005) The Peruvian Amazon: development imperatives and challenges. In: Palm CA, Vosti SA, Sanchez PA, Ericksen PJ (eds) Slash-and-burn agriculture: the search for alternatives. Columbia University Press, New York, pp 332–354